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Accuracy of intrapartum cardiotocography in identifying acidemia at birth by umbilical cord blood gasometry in high-risk pregnancies

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SUMMARY

OBJECTIVE: The aim of this study was to evaluate the accuracy of intrapartum cardiotocography in identifying acidemia at birth by umbilical cord blood gasometry in high-risk pregnancies.

METHODS: This was a retrospective cohort study of singleton high-risk parturients using intrapartum cardiotocography categories I, II, and III. The presence of fetal acidemia at birth was identified by the analysis of umbilical cord arterial blood pH (<7.1). Associations between variables were determined using the chi-square test and Kruskal-Wallis tests.

RESULTS: We included 105 cases of cardiotocography category I, 20 cases of cardiotocography category II, and 10 cases of cardiotocography category III. cardiotocography category III had a higher prevalence of cesarean sections compared to cardiotocography category I (90.0 vs. 42.9%, p<0.006). Venous pH was higher in patients with cardiotocography category I compared to cardiotocography category III (7.32 vs. 7.23, p=0.036). Prevalence of neonatal intensive care unit (NICU) admission was lower in neonates of patients with cardiotocography category I compared to cardiotocography category III (3.8 vs. 30.0%, p=0.014). Prevalence of composite adverse outcomes was lower in neonates of patients with cardiotocography category I compared to cardiotocography category II (9.5 vs. 30.0%, p=0.022) and cardiotocography category III (9.5 vs. 60.0%, p=0.0004). cardiotocography categories II and III had low sensitivity (0.05 and 0.00, respectively) and high negative predictive value (NPV) (0.84 and 0.91, respectively) for identifying fetal acidemia at birth. The three categories of intrapartum cardiotocography showed high specificities (96.0, 99.0, and 99.0%, respectively).

CONCLUSION: All three categories of intrapartum cardiotocography showed low sensitivity and high specificity for identifying acidemia at birth.

KEYWORDS: Pregnancy outcomes. External cardiotocography. Fetal blood. Blood gas analyses. High-risk pregnancy.

INTRODUCTION

Cardiotocography (CTG) is a dynamic intrapartum screening test capable of simultaneously recording fetal heart rate (FHR), fetal movements, and uterine contractions. The objective of this monitoring is to detect early fetal hypoxia and acidemia, analyzing the fetal oxygen reserve to support the stress of labor. CTG is indicated in situations of high risk of fetal acidosis, e.g., in pregnant women with hypertensive disorders, multiple gestations, gestational diabetes mellitus, and preterm birth[1].

However, intrapartum CTG in high-risk pregnancies has shown inconclusive benefits in some studies, not directly affecting perinatal mortality[2]. It is important to highlight that abnormal CTG patterns increase the rate of cesarean sections and instrumental deliveries, since the definitive diagnosis of hypoxia and acidemia depends on fetal blood collection[1].

Thus, to define the best way and time to terminate pregnancy, the CTG category system is used, which is based on baseline FHR, heart rate variability, and the presence or absence of decelerations. This system is divided into normal (category I) and abnormal (category III), both of which facilitate the definition of management. However, when the classification is undetermined (category II), it is indicated that continuous monitoring should be maintained until the category pattern changes, since it is a more challenging interpretation[3].

Although fetal acid-base physiology is similar to that of the newborn, compensatory forms of acidemia are different, and to identify this fetal alteration it is necessary to evaluate arterial and venous pH obtained by gasometry of the umbilical cord blood[4]. At birth, venous umbilical cord blood is rich in oxygen, since it represents the maternal-placental acid-base status, while arterial blood is rich in carbon dioxide, representing

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the neonatal acid-base status[5]. However, there is no consensus on when to perform arterial and venous pH analysis, but the American College of Obstetricians and Gynecologists (ACOG) and the American Academy of Pediatrics advise performing pH analysis after any delivery in which there is a risk of acidemia/hypoxia such as in CTG category III, instrumented vaginal delivery, and low APGAR score[3].

Therefore, the aim of this study was to evaluate the accuracy of intrapartum CTG for detecting fetal acidemia in high-risk pregnancies using arterial and venous umbilical cord blood gasometry.

METHODS

This was a retrospective cohort study conducted at the Mário Palmério University Hospital, University of Uberaba (UNIUBE), through the evaluation of medical records of pregnant women assisted during labor, from November 2019 to November 2022. The study was approved by the Research Ethics Committee of UNIUBE (CAAE: 52299421.7.0000.5145).

Singleton pregnant women with hypertensive disorders, diabetes in pregnancy, collagen diseases, maternal heart disease, decompensated pulmonary disease, epilepsy, hereditary thrombophilia, antiphospholipid antibody syndrome, chronic kidney disease, thyroid disease, moderate/severe maternal anemia, maternal infection (toxoplasmosis, syphilis, cytomegalovirus, parvovirus B19, and HIV), fetal growth restriction, oligohydramnios, fetal malformations, and chromosomal abnormalities were considered high-risk pregnancies[6].

CTG tracings were classified according to ACOG recommendations as follows[1]: Category I—normal tracings predictive of fetuses with normal acid-base status[2], Category II—non-reassuring tracings but not falling into category III and requiring further obstetric monitoring, and[3] Category III—abnormal tracings such as sinusoidal pattern, lack of variability, and frequent type II and III decelerations, among other changes associated with abnormal acid-base status[3].

After fetal expulsion, the umbilical cord was clamped at approximately 20 cm, and 1 mL of arterial and 1 mL of venous blood were collected in a 3 mL heparinized gasometry syringe (BD Luer-Lok, New Jersey, USA). Within 30 min of collection, the blood gas analysis syringes were transported to the hospital's clinical analysis laboratory. A Cobas b 221 gasometer (Roche Diagnostics, Switzerland) was used for cord blood gas analysis. The parameters to be analyzed in cord blood gasometry were arterial and venous pH[7,8]. A practical pH threshold to define pathological fetal acidemia was considered to be umbilical artery pH<7.1 and/or umbilical vein pH<7.2.

The following variables were assessed: age, ethnicity, smoking, number of pregnancies, pre-existing chronic diseases, obstetric risk classification (high-risk or usual-risk), gestational age at delivery, CTG category, type of delivery, time between cord clamping and gas analysis, arterial pH, venous pH, acidemia at birth, APGAR score at 1st min, APGAR score at 5th min, NICU admission, need for neonatal resuscitation, and early neonatal death (first 48 h). The adverse perinatal outcomes were considered to be the presence of fetal acidemia at birth, APGAR score at 1st min<7, NICU admission, need for neonatal resuscitation, and early neonatal death (first 48 h). The presence of at least one adverse perinatal outcome was considered a composite adverse perinatal outcome.

Data were transferred to Excel 2019 (Microsoft Corp., Redmond, WA, USA) and analyzed using the statistical program SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) and Prism GraphPad version 7.0 (GraphPad Software, San Diego, CA, USA). Quantitative variables were first subjected to a normality test (D'Agostino-Pearson), and those with a normal distribution were presented as the mean and standard deviation. Variables with non-normal distribution were presented as median, minimum, and maximum values. Categorical variables were described by absolute and percentage frequencies and presented in tables. The chi-square test was used to examine differences between categorical variables and their proportions. The Kruskal-Wallis test was used to examine differences between continuous variables. Dunn's post hoc test was used to compare pairs. The measurements of the primary endpoints were sensitivity, specificity, false positive rate, false negative rate, positive likelihood ratio, and negative likelihood ratio calculated from cross-reference tables. The significance level for all tests was $p<0.05$.

RESULTS

From November 2019 to November 2022, 2,861 pregnant women were admitted for labor. A total of 1,648 cases were excluded because of no CTG during labor, 899 because of no umbilical cord blood gasometry results in the medical records, 130 because of being classified as low-risk pregnancy, 29 because of inadequate umbilical cord blood conditions for analysis (blood coagulation, time between collection and analysis>30 min), and 20 because of a difference between venous and arterial pH<0.02. For the final statistical analysis, we included 105 cases of CTG category I, 20 cases of CTG category II, and 10 cases of CTG category III.

The clinical characteristics of the study population are shown in Table 1. Patients with CTG category III had a higher

Table 1. Clinical characteristics of the study population.

	CTG category I (105)	CTG category II (20)	CTG category III (10)	p
Age (years)	25 (15–43)	21 (15–35)	23 (16–35)	0.201†
Ethnicity				0.663§
White	47.6% (50/105)	35.0% (7/20)	60.0% (6/10)	
Black	11.4% (12/105)	20.0% (4/20)	10.0% (1/10)	
Mixed	41.0% (43/105)	45.0% (9/20)	30.0% (3/10)	
Smoking	10.5% (11/105)	20.0% (4/20)	0.0% (0/10)	0.235§
Number of pregnancies	1.0 (1.0–9.0)	1.0 (1.0–4.0)	1.0 (1.0–2.0)	0.053†
Number of deliveries				0.074§
Nulliparous	50.5% (53/105)	70.0% (14/20)	80.0% (8/10)	
More than one delivery	49.5% (52/105)	30.0% (6/20)	20.0% (2/10)	
Gestational age (weeks)	39.4 (35–40.9)[A,B]	38.4 (30.6–40.7)	38.4 (33.4–40.0)	0.014†
Type of delivery				0.032§
Vaginal	55.2% (58/105)	35.0% (7/20)	10.0% (1/10)	
Cesarean section	42.9% (45/105)[B]	65.0% (13/20)	90.0% (9/10)	
Forceps	1.9% (2/105)	0.0% (0/20)	0.0% (0/10)	
Time of labor (min)	240.0 (60.0–1,020.0)	240.0 (120.0–240.0)	180.0 (120.0–300.0)	0.358†
Birth weight (g)	3,260.0 (1,975.0–4,485.0)[A]	2,900.0 (1,440.0–3,360.0)[C]	3,280.0 (2,660.0–4,030.0)	<0.001†
APGAR score at 1st min	8 (1–9)[A,B]	7 (2–9)	7 (3–9)	0.006†
APGAR score at 5th min	9 (8–10)[B]	9 (6–10)[C]	8 (8–9)	0.002†
Arterial pH	7.22 (6.86–7.34)[A,B]	7.16 (6.91–7.22)	7.13 (7.01–7.26)	0.002†
Venous pH	7.32 (6.98–7.46)[B]	7.29 (6.99–7.38)	7.22 (7.12–7.35)	0.047†

pH: hydrogen potential; Kruskal-Wallis test†: median (minimum–maximum); Chi-square test§: percentage (n/N); [A]Category I vs. Category II; [B]Category I vs. Category III; [C]Category II vs. Category III; p<0.05.

prevalence of cesarean sections compared to patients with CTG category I (90.0 vs. 42.9%, p<0.006). Gestational age at delivery was significantly higher in CTG category I patients compared to CTG category II (39.4 vs. 38.4 weeks, p=0.002) and CTG category III (39.4 vs. 38.4 weeks, p=0.047). Birth weight was significantly lower in patients with CTG category II compared to CTG category I (2,900.0 vs. 3,260.0 g, p<0.001) and CTG category III (2,900.0 vs. 3,280.0 g, p=0.011). APGAR score at 1st min was higher in patients with CTG category I compared to CTG category II (8.0 vs. 7.0, p=0.012) and CTG category III (8.0 vs. 7.0, p=0.002). APGAR score at 5th min was higher in patients with CTG category I compared to CTG category III (9.0 vs. 8.0, p<0.001). Arterial pH was higher in patients with CTG category I compared to CTG category II (7.22 vs. 7.16, p=0.011) and CTG category III (7.22 vs. 7.13, p=0.005). Venous pH was higher in patients with CTG category I compared to CTG category III (7.32 vs. 7.23, p=0.036).

The association between intrapartum CTG categories and high-risk maternal conditions is shown in Table 2. Patients with gestational arterial hypertension showed lower rates of CTG category I than categories II and III (p=0.002).

A lower prevalence of APGAR score at 1st min<7 was observed in neonates of patients with CTG category I compared to CTG category II (6.7 vs. 25.0%, p=0.024) and CTG category III (6.7 vs. 40.0%, p=0.007). The prevalence of NICU admission was lower in neonates of patients with CTG category I compared to CTG category III (3.8 vs. 30.0%, p=0.014). The prevalence of composite adverse outcomes was lower in neonates of patients with CTG category I compared to CTG category II (9.5 vs. 30.0%, p=0.022) and CTG category III (9.5 vs. 60.0%, p=0.0004) (Table 3).

Patients with CTG category III, compared to those with CTG category I, had an increased risk of APGAR score at 5th min<7 (OR 9.3, 95%CI 2.42–38.77, p=0.007), NICU admission (OR 10.8, 95%CI 2.26–46.76, p=0.014), and composite perinatal outcomes (OR 14.3, 95%CI 3.76–48.69, p=0.004) without increasing the risk of acidemia at birth (OR 0.0, 95%CI 0.0–94.5, p>0.999).

Table 2. Association between intrapartum cardiotocography category and high-risk maternal conditions.

	CTG category I (105)	CTG category II (20)	CTG category III (10)	p
Maternal hemoglobin level <10 g/dL	21.0% (22/105)	25.0% (5/20)	10.0% (1/10)	0.630
Pre-existing and gestational diabetes mellitus	30.5% (32/105)	5.0% (1/20)	20.0% (2/10)	0.066
Gestational arterial hypertension	25.7% (27/105)	65.0% (13/20)	40.0% (4/10)	0.002
Chronic arterial hypertension	13.3% (14/105)	0.0% (0/20)	10.0% (1/10)	0.219
Pre-eclampsia	3.8% (04/105)	5.0% (1/20)	0.0% (0/10)	0.742
Fetal growth restriction	6.7% (07/105)	0.0% (0/20)	20.0% (2/10)	0.117

Chi-square test: percentage (n/N). A: Category I vs. Category II; B: Category I vs. Category III; C: Category II vs. Category III, p<0.05.

Table 3. Association between intrapartum cardiotocography category and adverse perinatal outcomes in high-risk pregnancies.

	CTG category I (105)	CTG category II (20)	CTG category III (10)	p
Acidemia at birth	1.% (1/105)	5.0% (1/20)	0.0% (0/10)	0.359
APGAR score at 1st min <7	6.7% (7/105)[A,B]	25.0% (5/20)	40.0% (4/10)	0.001
NICU admission	3.8% (4/105)[B]	15.0% (3/20)	30.0% (3/10)	0.004
Early neonatal death (first 48 h)	0.0% (0/105)	0.0% (0/20)	0.0% (0/10)	*
Need for neonatal resuscitation	1.0% (1/105)	5.0% (1/20)	10.0% (1/10)	0.118
Composite adverse outcomes	9.5% (10/105)[A,B]	30.0% (6/20)	60.0% (6/10)	<0.001

Chi-square test: percentage (n/N). *Impossible to apply statistical test due to the absence of outcomes. p<0.05. A: Category I vs. Category II; B: Category I vs. Category III.

We observed that intrapartum CTG categories II and III had low sensitivity and high negative predictive value (NPV) for identifying fetal acidemia at birth. CTG category I also showed low positive predictive value (21.0%). The three categories of intrapartum CTG showed high specificities (96.0, 99.0, and 99.0%, respectively). Intrapartum CTG was shown to be rarely useful in improving the ability to identify truly positive (low positive likelihood ratio values) and truly negative (high negative likelihood ratio values) individuals.

DISCUSSION

It is well known that CTG is a continuous and simultaneous recording of FHR, uterine contractility, and fetal movements, and this monitoring aims to identify fetal distress in order to avoid neurological alterations and even fetal death[9].

Previous studies have shown that alterations in intrapartum CTG in high-risk pregnancies contribute to higher rates of cesarean sections and instrumental deliveries[10,11], which is in agreement with this study since patients with CTG category III had a higher prevalence of cesarean sections when compared to CTG category II (90 and 42.9%, respectively). Moreover, this study showed a significant association between CTG and the presence of an APGAR score at 1st min<7, NICU admission, and adverse perinatal outcomes; however, there was no significant association between CTG and acidemia at birth, early neonatal death (first 48 hours), and need for neonatal resuscitation. Weissbach et al.[12], in a retrospective cohort study of 271 patients delivered by cesarean section for non-reassuring FHR, evaluated the duration of CTG category II, variability, tachycardia, and deceleration and correlated them with adverse perinatal outcomes. Patients with reduced FHR had higher rates of pH ≤7.0, and patients with fetal tachycardia had higher rates of APGAR scores at 1st and 5th min<7 and ventilatory support. Longer duration of CTG category II did not result in increased rates of adverse neonatal outcomes.

Intrapartum CTG aims to detect fetal hypoxia related to acute or subacute events during labor that require medical management to reduce the risk of complications such as hypoxic-ischemic encephalopathy, cerebral palsy, and neonatal death[13]. Thus, it is justified that high-risk pregnant women with a CTG category III had a higher prevalence of cesarean section compared to CTG category I (90.0 vs. 42.9%), since in case of alteration in intrapartum fetal monitoring, it is prudent to perform maneuvers to improve maternal-fetal oxygenation, and if monitoring remains inadequate, it is recommended for immediate delivery to avoid metabolic acidemia and tissue injury[14].

APGAR score at 1st min is an important parameter to help in the decision of neonatal resuscitation; however, the APGAR score is not a good predictor of intrapartum acidosis because it is a subjective parameter that depends on the experience of each professional[15]. In this study, APGAR score at 1st min was higher in patients with CTG category I compared to CTG category III, and 40% of patients with CTG category III had APGAR score at 1st min<7, while only 6.7% of patients with CTG category I had this same parameter, however, without observing the association between CTG category and acidemia at birth.

According to the ACOG as well as the International Federation of Gynecology and Obstetrics (FIGO), a normal FHR pattern with accelerations and the absence of decelerations on continuous assessment is predictive of good fetal oxygenation, requiring no additional interventions[16]. However, the presence of late and variable decelerations, bradycardia, and absence of variability may indicate high risk of acidemia at birth, necessitating delivery to avoid future consequences to the newborn[17]. However, a meta-analysis of randomized trials comparing different methods of intrapartum fetal surveillance found that none of them were associated with a reduced risk of neonatal acidemia, NICU admission, APGAR scores, or perinatal death. Compared with other types of fetal surveillance, intermittent auscultation seems to reduce emergency cesarean deliveries in labor without increasing adverse neonatal and maternal outcomes[18].

A study in high-risk pregnancies compared the FIGO 3-tier and 5-tier FHR classification systems to detect acidemia at birth. The 3-tier system showed a greater sensitivity and lower specificity to detect acidemia at birth and severe metabolic acidemia compared with the 5-tier system. The authors concluded that both systems presented a comparable ability to predict acidemia at birth, although the 5-tier system showed a better interobserver agreement identifying pathological tracings[19]. Such results differ from those found in our study, in which all categories of CTG showed low sensitivity to identify acidemia at birth, as well as high NPV. In addition, CTG category I showed low NPV and all CTG categories showed high specificity, indicating that CTG is rarely helpful to identify acidemia at birth.

CONCLUSION

All three categories of intrapartum CTG showed low sensitivity and high specificity for identifying acidemia at birth. Also, CTG category II and category III showed a high NPV for identifying acidemia at birth.

AUTHORS' CONTRIBUTIONS

ABP: Conceptualization, Data curation, Project administration, Visualization. **RSL:** Data curation, Visualization, Writing – original draft. **MFT:** Data curation, Visualization. **CGP:** Investigation, Validation, Visualization. **PTM:** Investigation, Validation, Visualization. **EAJ:** Methodology, Visualization, Writing – review & editing.

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